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Man-made changes of the relief due to the mining activities within Husnicioara open pit (Mehedinţi County, Romania)

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Abstract

Depending on the relief, the technological process for lignite extraction from Husnicioara open pit uses 2 or 3 excavation steps of the mine waste deposits that lie over the coal strata (I+IV); first, the mining waste is deposited in the outer spoil tip and then in the inner tip, followed by coal excavation on another step. So far, the mining activities have affected 3.5 sqkm, including part of the Lungă and Lacului Valleys, and Faţa Lacului and Pădurea Dumbrava hills. The area of the mining exploitation is an artificial space that functions according to new rules. Consequently, the study attempts to identify the man-made changes of the relief due to the mining activities using field measurements, Landsat satellite images and NDVI index. The results reveal that the lignite exploitation implies the dislocation, relocation and storage of materials, which has caused a significant change of the local geomorphological context, leading to the construction of some anthropic structures such as cavities and prominent relief forms.

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Keywords: Open pit; Geomorphological system; Landscape changes; Husnicioara

1. Introduction

Mining exploitation areas are artificialized spaces that function on the basis rules imposed by the anthropic-natural interaction. Anthropogenic changes vary in time [1] and space that is why it is difficult to establish the

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intensity with which they have occurred. The human impact on the relief has been widely described in the last years [2, 3, 4, 5] putting the right emphasis on environmental aspects of relief transformation [6].

Investigations of heavy metal pollution and seasonal changes in soil properties due to coal mine impacts were achieved in the current European researches [7, 8]. Thus, international regulations should be transposed into Romanian policy regarding environmental liabilities and the field of Environmental Justice, which would conduct to identifying and attaching a plurality of values to environmental damages [9]. More than that, many studies on land-cover explorations by processing of satellite images are becoming increasingly important tools for studying surface man-made activities on local and regional scales, e.g. determination of vegetation change using thematic mapper imagery [10]. Processing of 3D models and interactive visualization options represent important factors for the landscape modeling of areas affected by mining [11].

Mining areas in Romania present common negative aspects such as: anthropogenic disorganization of the network, partial modification or destruction of the aquifer layers, aggression of the biotic and pedologic domain, triggering or accelerating contemporary geomorphological processes [12, 13], aggression of the inhabited spaces and damages to population's health [14].

The research of the Lower Pliocene deposits from Husnicioara open pit began in 1989 [15] and have been continued till now. In 2000 Fodor et al. [16] analyzes the Romanian open pit lignite mining impact on soil. Contributions concerning the Dacian flora in southwesten Oltenia were brought by Diaconu et al [17] through analyzing the paleofloristic material collected from the roof of the IV-th coal layer.

This study aims to identify and value the man-made changes of the relief and environment at different stages of the Huşnicioara open pit life cycle. In order to identify the relief changes at spatial and temporal scale, on the one hand we intend to compare the initial relief with the actual one, based on cartographic documents and field measurements, and on the other hand we aim to analyze the impact of mining activities on vegetation with the help of Landsat satellite images and the interpretation of the NDVI index values.

Study area

Husnicioara open pit lies in the central part of the Mehedinţi county, 15 km from the county seat (Drobeta Turnu-Severin). The exploitation area is located between Negreşti settlement, in the north, Dumbrăviţa and Oprăneşti in the east, Gârdan Hill in the south and the cuesta that separates the Severin Depression from Coşuştea Hills in the West (Fig.1).

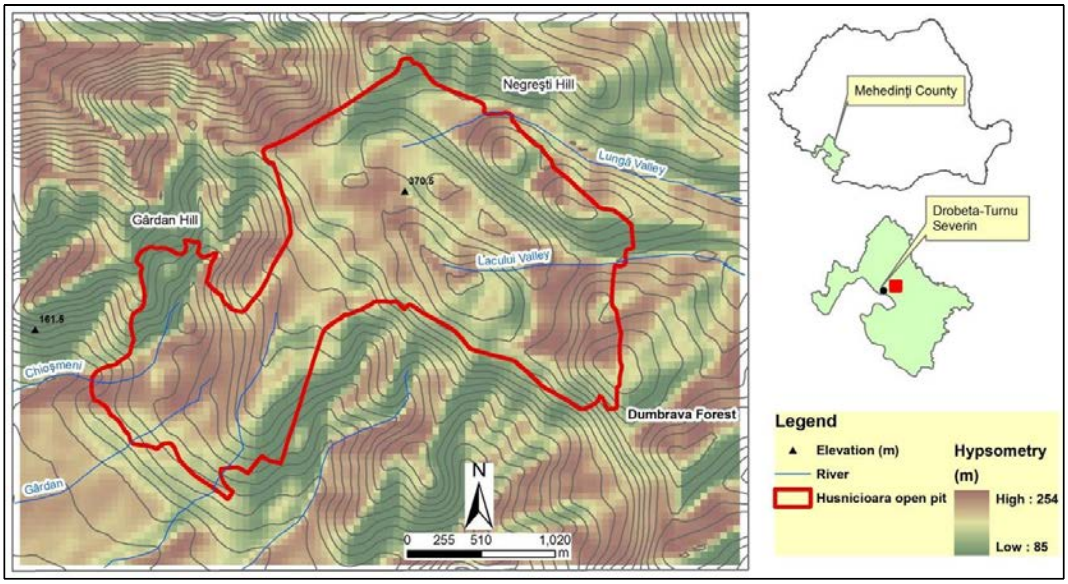
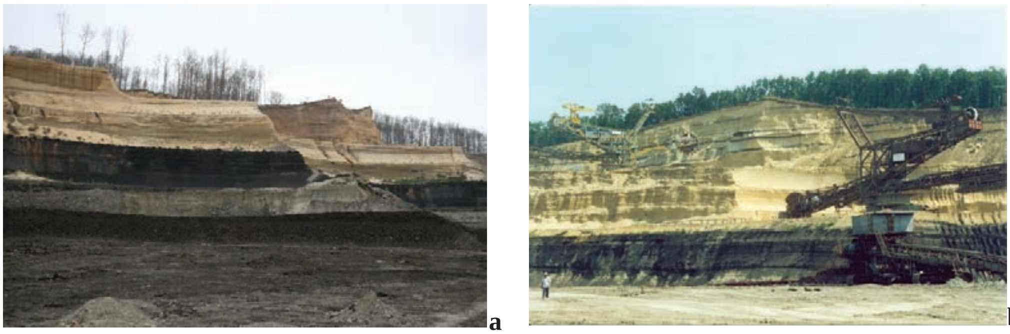


Fig. 1. Husnicioara open pit - national and regional location

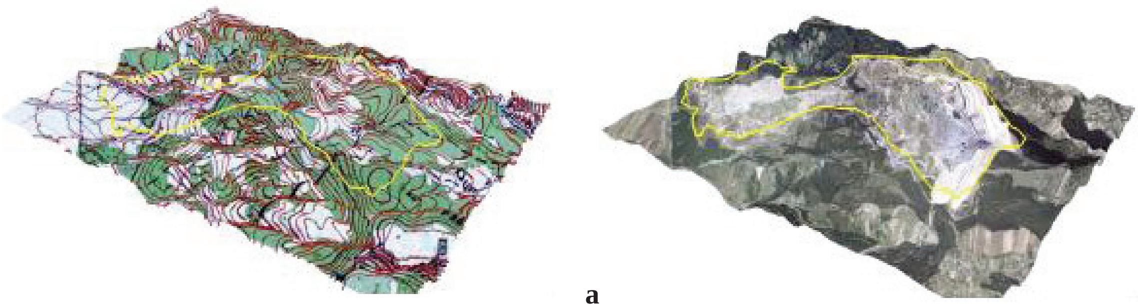
From the geologic point of view, the Pliocene-Quaternary deposits from this area are monocline, tilting south-eastwards, belonging to the Getic Piedmont [18, 19]. Only the fourth and the first strata are important from the economic point of view (8 meters and, 3 meters thick, respectively), located over the erosion base of the hydrostatic level. Depending on the relief, the technological process for lignite extraction from Husnicioara open pit uses 2 or 3 excavation steps of the mine waste deposits that lie over the coal strata (I+IV); first, the mining waste is deposited in the outer spoil tip and then in the inner tip, followed by coal excavation on another step (Fig.2).



a b

Fig. 2. Husnicioara open pit: (a) - the inferior step of coal exploitation with I and IV layers and the second stripping step; (b) - inferior and superior stripping steps of the career front

So far, the mining activities affected an area of 3.5 sqkm, including the Lungă Valley from its spring to the middle course, the Lacului Valley, and Faţa Lacului and Pădurea Dumbrava Hills. The Lungă Valley is located at the lowest level (290-300 m), while the highest peaks within the area are 370 m, 359 m, 356 m and 345 m (Fig.3). The northern limit borders the protection perimeter of Negreşti settlement in Negreşti Hill, stretching southwards to Gârdan Hill. These negative aspects disturb the ground and underground water circulation, lead to morphological changes of the riverbeds, change the flow dynamics, are aggressive towards the biotic and soil domains, trigger or accelerate the present geomorphological processes, pollute the natural components of the geomorphological system [20], change topoclimates, and not least, affect population's health [14, 21].



a b

Fig. 3. Husnicioara open pit draped on 3D surface derived from a SRTM raster file: (a) – topographic map view; (b)- orthophotograph view (orthophotos, ANCPI, 2009)

2. Materials and methods

Multispectral vegetation indices are represented by algebraic combination of remotely sensed spectral bands that can indicate the state of the vegetation cover.

A great deal of satellite data is commercially available in digital archives that offer a wide range of resolution scales and multispectral channels (e.g. ESRI, Change Matters). Thus, vegetation mapping and classification is used to enable prediction of human impact. The presented spatio-temporal modelling based on long time series from

LANDSAT images provides considerable experience for processing NDVI in the framework of identification of land-cover classes.

The normalized difference vegetation index (NDVI) is used to detect the land-cover changes:

$$NDVI = \frac{\rho n - \rho r}{\rho n + \rho r} \tag{1}$$

where ρn and ρr represent the reflectance of the near-infrared and red bands.

The resulting index value of a pixel typically ranges from around 0.1 to 0.6 for vegetation [22]. Understanding the relationship between NDVI and terrain attributes is of critical importance for protecting environmental and natural resources [23].The sources of information used in this study vary from cartographic materials to orthophotographs (0.5 m resolution, 2009, agricultural studies and environmental reports.

The draw up of the comparative sections of the open pit and outer spoil was performed starting from the natural profile extracted from the topographical maps 1:25.0000 (1978), and the current configuration has been drawn from the elevation measurements taken in the numerous field campaigns (using Leica FlexLine TS09 plus 3'' R30 Total Station) conducted in 2011.

3. Results and discussions

The analysis of man-made changes on the relief due to the mining activities within Husnicioara open pit was conducted in two stages. In the first stage, it has been done the comparison between the initial relief with the actual one based on cartographic documents and field measurements. In the second stage, the mining activities impact on vegetation was analyzed with the help of Landsat satellite images and the interpretation of the NDVI index values.

The geomorphologic modelling caused by the lignite exploitation in Husnicioara open pit is based on the truncation of some hills and the lowering of the open-pit bottom well below the level of the local hydrographical network. It is also worth mentioning here the construction of new micro-relief forms, such as the platform of the inner spoil tip (Fig.4,5,6,7), the obstruction of the upper basin of some gullies with the mine waste of the outer spoil tip (Fig. 8,9,10). The outer spoil tip of Husnicioara open pit covers 1.5 sqkm. Gârdan and Chioșmeni gullies lie at an altitude of 170-175 m, while the slopes reach 250-275 m.

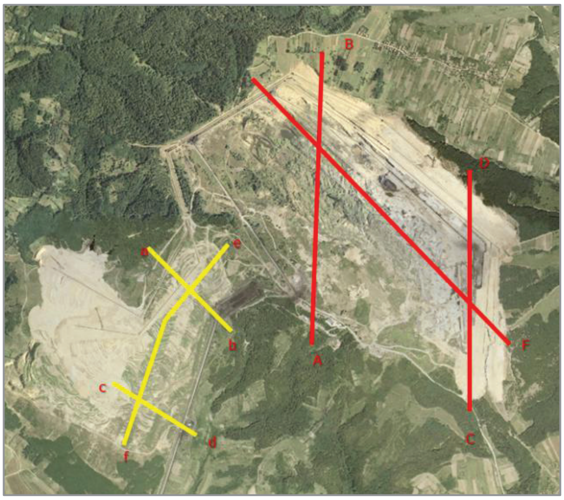


Fig. 4. Location of the open pit and outer spoil tip *A – B, C – D, E –F sections in the open pit; a – b, c – d, e – f, g – h sections in the outer spoil tip* (*processed after ortophotos, 2009*)

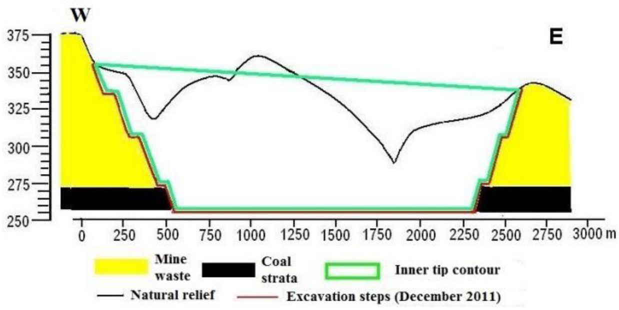


Fig.5. A-B Cross section through the quarry

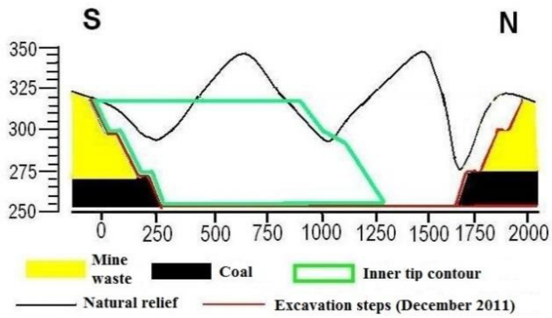


Fig.6. C-D Cross section through the quarry

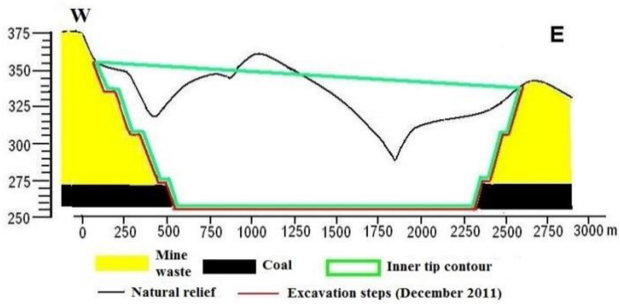


Fig. 7. E-F Longitudinal section through the open pit

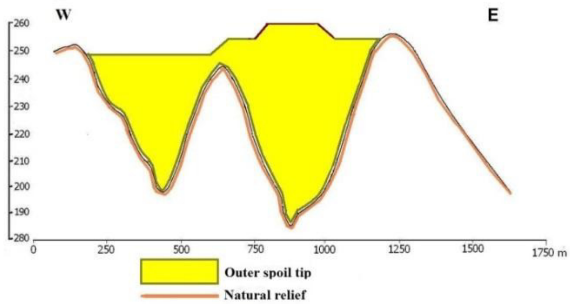


Fig. 8. a-b Cross section through the upper part of the outer spoil tip

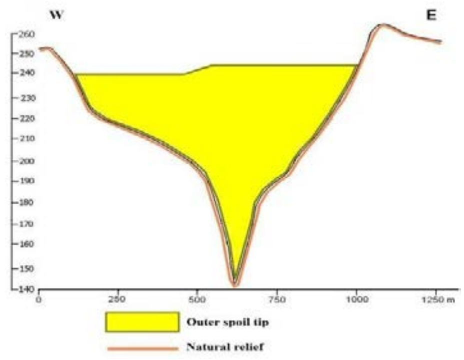


Fig. 9. c-d Cross section in the lower part of the outer spoil tip

For the outer spoil tip, where the mine waste was deposited at the beginning of the exploitation works in Husnicioara open pit, the upper course of the Gârdan valley was chosen because of the tight cross section. At present, the spoil tip is situated at the springhead of Chioşmeni gully. This location offers good stability, the slopes being higher than the upper part of the spoil tip. The only potential risky section is the one lying downstream. Starting from the profile made for the present slope wall of the tip on this valley, there was measured an angle slope of 40, meaning that at present the spoil tip is stable.

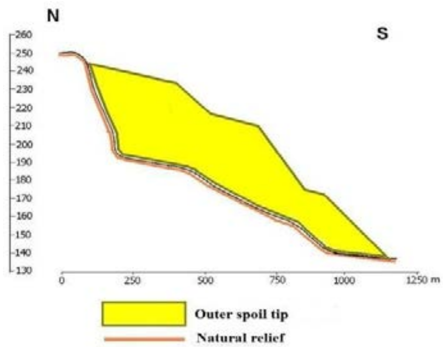


Fig. 10. e-f Longitudinal section through the outer spoil tip

Still, the morphology of the spoil tip is continuously changing, depending on the composition of the mine waste (more clay or less sand) and on the slope walls. The morphology of the outer spoil tip, as well as of the inner one, can change in terms of slope and destabilising phenomena (rain-wash, sheet-wash, mass movements etc.). Such a phenomenon took place in 1990, when abundant rains led to the flooding of the region, affecting also the upper step of the outer spoil tip, causing ravines and drainage ditches. Two forests, Dumbrava and Negoieşti, were destroyed, and the ones on Gârdan Hill and Dumbrava Forest were chopped.

These results are similar with those of other studies, such as: changes induced to the geomorphologic systems as a consequence of lignite exploitation in Oltenia [12], the pressure exerted on the natural environment in the open pit exploitation areas in Oltenia [21], and some aspects regarding the Romanian open pit lignite mining impact on soil [16]. The Landsat satellite images have been included in the data processing, based on the ESRI open source analysis programme ChangeMatters. The purpose of using them consists in land-cover mapping because of the relatively long data record period and the high multispectral spatial resolution.

The time series of Landsat images covering the 1990–2010 period is used here to explore the impacts of surface mining and reclamation. The image processing techniques are based on pixel-by-pixel calculation of the vegetation index, such as NDVI (free access by ChangeMatters - ESRI). This method would be useful to identify areas where vegetation may be stressed, or where reclamation may be failing.

The main trends related to mining activities during the long-term period can be clearly understood, as well as the decrease of vegetation areas: from 3.4 sqkm (1990-2000) and 3.2 sqkm (2000-2005) to 3.8 sqkm (2005-2010) (Fig.11). It is clear that the values of NDVI increased with the altitude within the studied area.

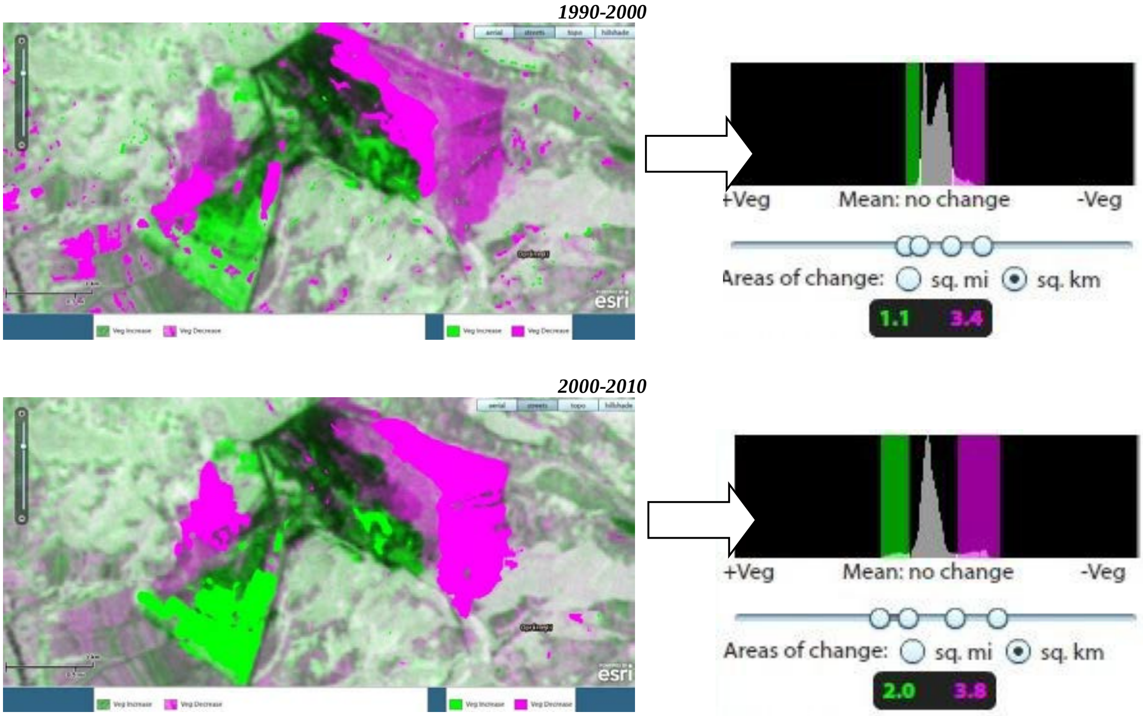


Fig. 11. Time-scale change of vegetation dynamics within the study area during the 1990-2010 period (*source: ESRI - Change Matters*)

The anthropic activity and the morphological characteristics generated:

- an area with average and high geomorphological risks for gravitational and hydrological processes;
- rapid spread of the areas affected by erosion and mass-movements;
- the new relief forms are characterized by greater energies and instability;
- the technologies used were not always compatible with the carrying capacity of the environment;
- the removal of mine waste strata, dozens of meters thick, radically changes the landscape, and destroys fertile lands;
- significant changes in the vegetation, deforestations and replacement of woods with field of *Botriochloa ischaemum* [12].

4. Conclusion

The anthropic activities from Husnicioara open pit have a direct and indirect influence on the relief: directly, it changes the natural equilibrium of the terrain and the modelling processes, by inducing changes in the superficial flow regime and diminution of the flows feeding some gullies, by covering their springhead with materials from the open pit; their indirect influence is marked by the changes of some geosystem components (deforestation, changes of the slopes, remodeling of the micro-relief).

Taking into consideration the necessity to reduce the atmosphere pollution with dirt from the spoil tips, made predominantly of dusty and sandy deposits and the urge for the management of tips, it was decided that they should be afforested. For this purpose, locust was chosen because of its resilience to drought, quick development and abundant tree crown.

On the inner tip, the recultivation of locust trees began again in 2010, on its southern part, from the final embankment of the open pit. In order to ensure a greater stability of the outer spoil tip from Gârdan gully, locust trees were also planted beginning from the lower part of the embankment.

The presented spatio-temporal modelling based on satellite images, and focused on assessing land cover changes within the Husnicioara open pit provides considerable experience for processing archive data and satellite data obtained in the future. Other socio-environmental liabilities can be applied for the Husnicioara open pit impacts such as: air pollution, soil-mining waste, loss water quality and population relocation. Also, a particular attention must be paid to the local human health.

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